Climate Change Fuel Cell Program

National Grid USA Service Company,
Successor to New England Power Company,
Regarding a 200-kW Fuel Cell Powered by
Digester Gas on Deer Island, Boston, MA

Final Report

Report on the life of the installation, from September, 1997 to June, 2002

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ABSTRACT

The New England Power Company (now a subsidiary of National Grid USA) purchased an ONSI (now UTC) PC25C 200-kW fuel cell for use at the Massachusetts Water Resources Authority (MWRA) Deer Island Sewage Treatment Plant in Boston Harbor in 1997. Anaerobic digester gas (ADG), a methane-rich byproduct of sewage treatment, was processed by a gas pretreatment unit (GPU) designed to remove sulfur, moisture and other impurities. The treated gas was consumed in the fuel cell to make electricity, and the excess heat produced in the process was transferred to the atmosphere by a cooling module. Due to limitations on ADG supply, problems in very cold weather and fuel cell component failures, this unit did not run for extended periods of time during its four and one-half years on Deer Island. The MWRA exercised its option not to take ownership of the unit, and it was removed from the site in 2002.

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Executive Summary

This project began under the direction of the New England Power Company, based in Westborough, MA. Since the fuel cell was located on Deer Island, approximately 35 miles to the east and a site with both difficult access (due to geography) and highly-restricted access (due to construction of the main wastewater-treatment facilities), the project did not have the benefit of direct and frequent supervision by NEP. The MWRA did make a technician on Deer Island available for specific tasks at the request of NEP. This person also tried to monitor the status of the unit each day, but fuel cell efforts were always subordinate to his normal work responsibilities. In 1999, as a result of electric utility restructuring legislation in Massachusetts, NEP transferred ownership of the fuel cell to the Massachusetts Electric Company and project supervision to the New England Power Service Company (NEPSCo); this company later became National Grid USA Service Company (NGUSC).

The Deer Island project was the second of its kind (fuel cell powered by ADG) in the US, and definitely experimental. The purchase contract explicitly stated that the system was being sold " … WITHOUT ANY WARRANTY OF ANY KIND …" in view of its experimental/prototype nature. NGUSC and the MWRA made good faith efforts to keep the fuel cell operational, but the system never ran continuously for more than four weeks. The MWRA had the option of assuming ownership and operational responsibility at the end of the five-year contract period with National Grid, but declined due to high maintenance requirements and unfavorable economics, relative to other options for the use of ADG onsite. The fuel cell was decommissioned and removed by National Grid in June of 2002.

Introduction and Overview

The MWRA was interested in the educational value of this fuel cell system, and wanted to site it in an area where it could be viewed by the public. The fuel cell was therefore located behind the combination reception building and visitors center. Within this building, a custom-built display with audio and video features described how the fuel cell made electricity from ADG. Unfortunately, this location was about a mile from the digesters (the source of ADG) so that gas had to be provided to the fuel cell using a compressor system. Operation during the first two years was hampered by low gas flows, due in part to regular compressor failures along the pipeline. Had the fuel cell been sited near the digesters, it might have received a more continuous gas flow and may have exhibited better performance.

ADG itself presented additional challenges. The lower Btu content per unit volume meant that in practice the fuel cell could only operate at part load (a maximum of 175 kW, with more reliable operation at 150 kW). If gas flow was insufficient for the programmed power level, the fuel cell management system would turn the unit down to 75 kW. The high moisture content of ADG also caused problems in winter. During very cold weather (15 degrees F or below), the gas regulator would freeze due to the moisture-rich ADG, restricting the gas supply and causing the fuel cell to shut down. National Grid arranged for a contractor to wrap all vulnerable components and piping with insulation and heating tape to eliminate this problem.

Start-up of ADG plants is also more complex than running a fuel cell on natural gas, because it has to begin operation on bottled methane and then be transitioned to ADG. This requires several hours of dedicated oversight and a high degree of skill at managing temperatures within the fuel cell.

When the fuel cell isn't operating, pumps still need to circulate water to maintain the internal temperature of the cell stacks. This is known as "water conditioning" mode. For unknown reasons, the "lock-out" relay on the Deer Island fuel cell would trip frequently when the system was in water conditioning mode, shutting down the pumps. This limited the potential use of the fuel cell and increased the level of attention required of on-site maintenance personnel.

When it became clear from operational problems that this system needed more extensive and knowledgeable attention, National Grid arranged for the MWRA technician to attend a week-long training program offered by the manufacturer. As component failures occurred, National Grid paid for UTC personnel to travel to the site and the cost of new components. This continued even beyond when the MWRA declined ownership, up until the week before the unit had to be removed from the site.

Results and Discussion

1. Mean Time Between Failures

If failure is defined as an event that caused the fuel cell to cease operation, during the course of this project there were too many failures to keep track of – in part because of the remote location and in part because personnel were not available to monitor this unit 24 hours per day. Although some failures were due to external conditions (e.g., very cold weather), the unexplained lockout relay problem was never solved despite much study and parts replacement during several visits by UTC technicians.

2. Costs & Benefits

The initial cost of the fuel cell system, its installation and all subsequent maintenance and repairs were paid by National Grid. Total costs were on the order of $2 million. The direct monetary value of using ADG from wastewater treatment for electricity production is due to the reduction of electricity used by the Deer Island facility. In the initial years of the project this electricity was purchased from another utility. The terms of this power purchase contract are not publicly available, but a reasonable assumption for the energy cost is 8 cents per kWh. Since the fuel cell produced 665,000 kWh, the value/benefit is $53,200 using the assumed electricity cost. Later, ADG was piped to a conventional boiler and power plant on the island, so that the marginal value of electricity produced by the fuel cell was less. Its prime non-monetary contribution was in the reduction of greenhouse gases (ADG, primarily methane) from the digester before the main Deer Island power plant was available.

After five years, the fuel cell stack has less than 4,500 hours of operation, which means the fuel cell could be used for approximately 35,500 more hours before stack replacement is required. Efforts to start the unit prior to its removal uncovered a problem in the reformer section, which would require roughly $15,000 to repair according to UTC personnel. To summarize, costs have far outweighed the direct monetary benefits of this project, but it has helped to advance the concept of treating digester gas from wastewater facilities to provide a low-cost fuel.

3. Reliability

For the many reasons mentioned previously, this has not been a particularly reliable fuel cell system. Problems have occurred in the reformer, the water conditioning system, the fuel cell stack, the inverter and the control system. Most problems were solved, but the reason for apparently random operation of the lockout relay (causing the unit to shut down) has never been determined.

4. Thermal Output

Although piping was installed from the fuel cell site so that hot water could be provided to the visitor center nearby, the concept was never taken up by the MWRA. Excess thermal energy was therefore discharged to the atmosphere via a cooling module consisting of three fans and a heat exchanger.

5. Certification

National Grid USA Service Company certifies that it has complied in all respects with the grant under DE-FG21-96MC33336, Climate Change Fuel Cell Program, and that the related efforts required by that grant are now fully complete including twelve months of operation and submission of the Final Report herein supplied. Such Report is in compliance with the Department of Energy's Special Terms and Conditions for Research Projects Grants for the Climate Change Fuel Cell Program.

Conclusions

This was clearly an experimental project, with very complex equipment operating in an uncertain environment located on a third party's property remote from the project owner. Lessons were learned regarding operation in very cold weather, and a solution was found.

If this concept of using ADG for a fuel cell is to be developed further, it is recommended that the owner of the equipment assign an employee located in close proximity to the system to monitor the unit on a regular basis.

Since the unit was never able to reach full power (200 kW), it is suggested that redesign of the fuel cell control system and/or components is in order.

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